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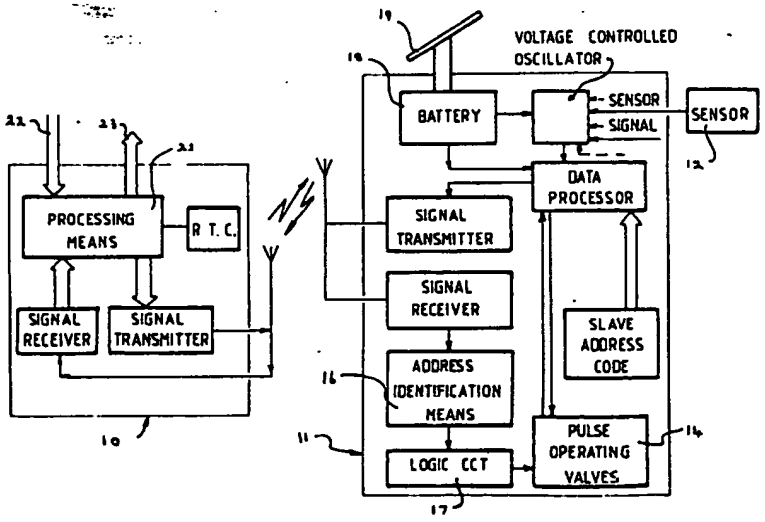

(57) Abstract

A remote process control system particularly for irrigation incorporates a master controller (10) and a plurality of controller units or slaves (11) which communicate with the master controller (10) using digital information and control signal transmissions. Each controller slave (11) is associated with a section of the irrigation system such as one or more water sprinklers, and includes sensors (12) for measurement of temperature, wind velocity, soil moisture levels and/or water flow rate meters. Each controller unit or slave (11) controls a water valve (14) to the associated part of the irrigation system. The master controller (10) receives data from each of the controller units or slaves (11) and, subject to a predetermined program and the transmitted data from the slaves (11), signals the respective slaves to operate their respective water control valves (14). During operation, the master controller (10) continually monitors the parameters sensed by the slaves (11) and controls the respective water valves (14) in accordance with those sensed parameters and the predetermined operational program such that each slave (11) is separately controlled in accordance with the sensed parameters associated with that portion of the irrigation system.

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REMOTE PROCESS CONTROL APPARATUS

Background of the Invention

This invention relates to remote process control apparatus of the kind used for controlling a process, function or operation from either a remote or a central location. The apparatus of the present invention has been particularly developed for remote control of an irrigation operation, e.g. for agricultural and horticultural uses or for use on areas such as golf courses, and it will be convenient to describe the present invention particularly in relation to agricultural use. However, it will be appreciated that the invention is applicable to other remote process control situations, such as remote control of multiple operating mechanisms, e.g. security systems including, say, locks on access gates and doors, lighting in large buildings, process control points in large processing installations and the like.

Background Art

It is known that irrigation requirements vary depending upon the particular crop, the soil type, the stage of development of the crop and weather conditions. Generally, in the past, a farmer must judge all these variables at regular intervals and make decisions on the amount or supply rate of water needed. The timing of opening and closing valves to supply the irrigating apparatus such as drip feed lines or sprinklers has frequently been carried out manually based on the farmers' estimations of crop requirements. Of course, printed data available from the appropriate Government Department of Agriculture or the like has assisted the farmer in making his estimation of water needs.

Various forms of automatic control for irrigating crops have been proposed. United States Patent 4,176,395 to Evelyn-Veer et al discloses a control system for a number of remote irrigation valves in accordance with schedules of instructions. Operation of the control system can be in response to sensed parameters or under program control or under manual operator control. This system

is designed so that the instruction schedules can be created and/or modified during operation of the system without disrupting the operation. However, the system relies on individual wire pairs for sending signals from the controller to individual field stations which is relatively inefficient and uneconomic. Further, this system requires continually refreshing or regenerating output signals which are transmitted to the field stations to maintain valves controlled thereby in the intended condition. Thus, the output data is repeatedly transmitted to the various field stations.

U.S. Patent No. 4,161,718 to Motorola Israel Ltd. discloses a control system for monitoring and supervisory functions in a noisy electrical environment using radio and/or telephone line communication channels. The specification discloses the use of transmission of two coded identification signals which are compared for similarity. With bad transmission conditions, however, the transmission of two coded identification signals may be insufficient to ensure correct operation of the system.

U.S. Patent NO. 4,270,185, also to Motorola Israel Ltd., also describes a control system having a central control station linked by radio or telephone lines to status stations and which uses a coded signal which is checked on reception to avoid errors resulting from noisy transmission environment. This system, however, uses repetitive transmissions of coded pulses which update the central control station.

British Patent No. 2,052,106 in the name Fenlow Irrigation Ltd. discloses a soil irrigation system using probes which sense the soil moisture level which is compared with a reference to control irrigation. The rate of change of the output of the probe is detected and, if that rate exceeds a preset rate, the reference is automatically shifted to compensate. A multi-channel controller controls irrigation separately to a number of areas. This system relies on the rate of change of detected soil moisture content to effect changes in irriga-

tion parameters.

Australian Patent No. 539,110 in the name Motorola Israel Ltd. discloses a further form of irrigation controller which controls a number of remote stations each having main metering to measure the quantity of water distributed by the associated irrigation system. The water metering generates pulses for each predetermined quantity of metered water and the central control receives inputs from monitors and instructs the remote station to shut a control valve when a desired quantity of water has issued. This system, like other similar systems, are continuous polling systems which receive interrogation signals from the central control and send status information to the control following such interrogation. Because of time constraints, the length of time necessary to transmit a valid signal with coded data, such systems have a limited number of stations with which they can be operated.

It is an object of the present invention to provide apparatus for remote control of operating mechanisms or processes and which enables centralised control of process operations at many remote locations with relevant data for each location being taken into consideration.

It is an object of a particular preferred embodiment of the present invention to provide improved remote irrigation control apparatus enabling accurate irrigation control at a plurality of remote locations based on the water needs of the crop at each location.

Summary of the Invention

The remote process control apparatus according to the present invention includes a master controller and a plurality of process controller units or "slaves" which communicate with the master controller and which are operative to control respective process operations under the control of the master controller. The master controller includes signal receiving means for receiving from each slave a parameter data (telemetry) signal relating to the status of at least one process parameter at the respective slave, processing means coupled to the

signal receiver for determining the status of the process at each slave and for determining changes in the process operation controlled by each slave, and a signal transmitter coupled to the processing means to transmit to each slave respective command signals.

Each process controller slave may include a power supply for operational components of the slave, a signal receiver for receiving from the master controller the command signals, address identification means for identifying which signals received by the signal receiver constitute command signals addressed for that slave, a logic circuit coupled to the address identification means for receiving command signals and being operative to control an associated process or operation in response to command signals, and a signal transmitter for receiving from parameter sensing means associated with the slave a sensor signal representative of the sensed status of the or each process parameter at the slave, the signal transmitter being operative to transmit the parameter data signal to the master controller indicating the status of the or each process parameter.

Alternatively, each process controller slave may be interconnected with each other and with the master controller by a single, two wire, signal transmission cable. This cable can be used for the transmission of signals as well as for the transmission of the power necessary to both operate the slave and to operate any peripheral devices associated with the respective slaves.

Using the remote process control apparatus as outlined broadly above, it is possible for a single master controller to simultaneously maintain control of a plurality of processes under control of respective slaves, the status of one or more parameters of the process at each slave being available at the master controller so that accurate decisions can be made regarding desired changes to the processes being controlled. The command signals are addressed to individual respective slaves thereby providing independence of control of each slave.

In one preferred form, the master controller communicates with the individual slaves by dual carrier transmission of binary pulses, preferably using radio transmission. The dual carrier system has a main carrier at a relatively high frequency, for example 305 MHz, with a sub-carrier at a relatively low frequency such as, for example 32 KHz. The master controller and slaves are crystal locked to the sub-carrier which provides a very accurate means for avoiding stray transmissions which otherwise could adversely effect the system operation. At the same time, while the transmitted main carrier frequency can vary, due to power variations, component factors, etc., the broad range master controller and slave receivers are able to receive the carrier and pick out the signal on the sub-carrier.

The signal transmission preferably comprises 32 bit binary pulses which include 8 address bits, 8 parity bits and 16 data bits. Each slave has its own unique address code so that each is separately addressable.

It is also a feature of the invention that the master controller, or a secondary controller having similar functions, is portable. This requires the controller to be able to be battery powered either with its own inbuilt batteries or from an external battery source such as a vehicle battery.

If slaves are located at remote and/or dispersed sites, signal repeater stations may be required to receive and re-transmit command and status signals. Any malfunction of any repeater or a slave or any servicing, maintenance, replacement or other work which must be carried out at the site of a repeater or slave can be performed taking the master controller, or a similar secondary controller, to that site. The system remains fully operational and enables a single operator to maintain total control at all times. Thus, a repeater failure is able to be checked by by-passing the repeater and site checking the operation of the slave by taking the master controller to the slave site.

The power supply of the process controller slave may comprise any convenient supply. For example, if readily available, the power supply may comprise a normal mains power supply from a public or other network. However in the case of the preferred application of the control apparatus in irrigation control, it is expected that a suitable mains power supply often may not be readily accessible where the slave is located in use. Therefore, the power supply preferably comprises a battery and may also include a solar panel for providing a charging current for the battery to maintain the battery fully charged. Because of the low power demand of the slave to be described, a long life of the battery is expected.

In another preferred embodiment the signal receiver of the slave comprises an input line for connection to an electrical cable running from the master controller and for carrying the command signals. A single cable (single wire pair) may be used for all the slaves with the slave input line tapping into the cable, enabling the similar slaves to all receive command signals from the single cable.

In alternative embodiments, control signals may comprise microwave or light or pulsed or modulated laser transmissions, and an appropriate receiver would be used.

In accordance with a particular aspect of the invention, the remote process control apparatus comprises a master controller and a plurality of slave units located remote from the master controller, each slave unit having one or more inputs receiving input signals from at least one sensing means and one or more outputs to control at least one process or operation, signal transmitting and receiving means associated with each slave unit to receive signals transmitted by the master controller and to transmit information thereto, said master controller including a programmable microprocessor and means for inserting program instructions, input means for receiving parameter signals from parameter detecting means, and control signal generating means to generate coded control

signals for transmission to said slave units in accordance with programmed instructions, said master controller communicating with any of said slave units when a change of parameters beyond predetermined values occurs or at predetermined times or following signals transmitted by a slave unit in response to an input signal, and lock-out means on each slave unit and said master controller to prevent transmission at any one time of more than one control or other signal by a slave unit or the master controller. Preferably, each slave unit also includes a programmable microprocessor which can control functions associated with the slave unit independently of or in conjunction with the program of the master controller.

Input signals are received by each slave unit from one or more sensors adapted to sense soil moisture content, water flow, filter condition, motor operation, pump operation, air temperature, wind speed, precipitation, daylight, fertilizer flow or injection, evaporation rate, soil temperature, battery condition, power supply, radio signal strength or any other condition or parameter associated with the system being controlled.

In order that the invention will be more readily understood, one embodiment thereof will now be described with reference to the accompanying drawings, wherein:

Figure 1 is a block diagrammatic illustration of an irrigation control system incorporating the features of the present invention,

Figure 2 is a block diagram of a master controller for use in the present invention,

Figure 3 is a block diagram of a field station in accordance with the invention,

Figure 4 is a circuit diagram illustrating part of the circuit of a signal transmitter,

Figure 5 is a circuit diagram of part of the circuit of a signal receiver,

Figure 6 illustrates the master controller facia, and

Figure 7 is a block diagram illustrating signal

collision avoidance.

Description of the Preferred Embodiment

The embodiments of the invention shown in the drawings for purposes of illustration show the invention for use in an interactive irrigation control system having a large number of electrically actuated irrigation valves which are to be actuated under the program control to control crops in accordance with sensed parameters and other factors which will affect the irrigation.

The system is broadly shown in Figure 1 where a master controller 10 controls a plurality of remote and spaced field stations 11 using radio telemetry or a single two-wire cable. Figure 1 illustrates a two-way radio link.

In the embodiment shown in Figure 1, each field station 11 controls at least one irrigation control valve 14 in accordance with signals transmitted by the master controller 10 to the respective field station 11. Each field station may also include one or more sensors 12 for sensing valve condition, water flow, soil moisture content, temperature, wind speed or any other suitable parameter. Input signals from the sensors 12 are fed to a data processor, and if sensed parameters vary from preset values, the field station automatically transmits a signal to the master controller 10 indicating the sensed value or change. The master controller 10 may as a result of programming, manual actuation or in response to a received signal, transmit a control signal to the field station 11. The control signal includes an identity code which allows the master controller 10 to identify the particular field station 11 for which the control signal is meant. A comparing circuit 16 at the field station 11 compares the address code of the control signal with a unique preset code before the field station 11 is enabled.

A logic circuit 17 coupled to the comparing circuit 16 responds to recognition of the incoming signal to control the associated valve 14 in accordance with the

process operation status command transmitted by the control signal. In the case of the field station 11 controlling an irrigation valve 14, the logic circuit may be arranged to control water supply to an associated crop. If desired, fully proportional control of the valve 14 may be provided so that any valve state from fully open to fully closed can be provided. Also, if desired, the logic circuit 17 may be arranged to control other process operations, such as feeding of fertilizer into the irrigation water being supplied to the crop.

The field station 11 may be supplied with electrical power from any suitable source. More conveniently, however, because of the remote location of the field stations 11, a battery power supply 18 is used. The battery 18 may be maintained in a substantially fully charged condition by means of a solar battery charging device 19. Further, power utilization is kept to a minimum by the preferred use of pulse operated valves which are operable between opened and closed positions in response to supply of a relatively short pulse of electrical energy. Such a valve includes an inlet and an outlet both communicating with a substantially cylindrical valve chamber in which is located a valve member. The valve member is biased by biasing means, such as a compression spring, into either a normal valve open position, in which flow can occur between the inlet and outlet through the valve chamber, or a normal closed position in which flow from the inlet to the outlet is prevented.

The valve member is axially movable against the action of the biasing spring from its normal position (either normally open or normally closed) to its other operative position in response to supply of power to a solenoid associated with the valve. For this purpose, the valve member is either made of a ferro-magnetic material or has ferro-magnetic end portions so as to be movable by the magnetic field set up upon supply of power to the solenoid.

Simultaneously with supply of power to the

solenoid, power may also be supplied to a valve member latch which normally prevents movement of the valve member from one of its positions to the other but which, when energized, allows such movement. After the valve member has moved against the action of the biasing means from its normal to its operative position, the valve latch returns to a position in which it will again prevent movement of the valve back to its normal position under the action of the biasing means. This supply of power to the valve member solenoid can then be discontinued without the valve returning to its initial condition. Thus, the valve can change state in response to a relatively short and small supply of energy.

The master controller 10 incorporates processing means 21 which may conveniently comprise a microprocessor and associated peripheral equipment. The processing means 21 is programmable via a key-pad input 22 and has an output 23 to a VDU, panel display and/or printer.

Referring particularly to Figure 2, the master controller 10 is able to communicate with a field station 11 either via a radio link established by the radio transmitter and receiver 24 or by a two-wire cable which may also be used to transmit power from the power supply module 26 to the remote field stations 11.

It is a feature of the invention that the master controller 10 is portable and is, therefore, able to be taken to the field station sites to check operation thereof and for maintenance and servicing. For this purpose, the power supply 26 is associated with an emergency battery supply 27, may be connected to a mains power supply or can be connected to an external battery supply, such as from a vehicle battery.

Control of the master controller 10 may also be effected via a telephone line or a direct telecommunication line using a modem 28. This enables the master controller 10 to be located at a working station and be controlled from an operators home through a personal computer set up to receive data and transmit data to the master

controller and to even program or reprogram the master controller.

The central core of the master controller 10 is the central processing unit 31 which is programmed via the key-pad and program entry unit 32 or by signals transmitted via the modem 28. With the embodiment of the invention utilizing intelligent field stations 11, the central processing unit 31 may also be programmed from a remote field station.

The irrigation system controlled by the master controller 10 is dependent for its operation on prevailing weather and other conditions. The master controller 10 therefore receives input signals from various parameter sensing devices such as a weather station 33, evaporation measurement device 34, and the like. The weather station 33 provides signals indicative of wind speed and air temperature, which signals are passed to signal conditioning units 36 and 37, respectively for transmission to the central processing unit. Other signals are received from the evaporation measurement device 34 and from any external analogue signal source.

If an input signal is detected which indicates that the sensed parameter has exceeded or fallen below preset values appropriate action is initiated under program control which may require a valve shutdown or opening, a total system shutdown (if a predetermined maximum wind speed is exceeded), or other system operation. The program will, therefore, call for the generation of an appropriate control signal and will determine to which field station the signal is transmitted and will generate the appropriate address codes to enable the signal to be transmitted either by radio or by cable to the selected field stations.

The master controller 10 has several internal checking functions including a communication level sensor 38, internal battery level sensing 39 and the like. If the appropriate sensors detect levels below preset levels, an alarm is initiated. Similarly, an alarm initiation occurs if a field station sensor fails or if a sensor

detects failure in equipment or operation. Visual and audible alarm indicators are initiated and, if desired, an alarm signal may be transmitted to a personal pager carried by the system operator.

Referring to Figure 3, the block diagram schematically illustrates an intelligent field station 11 which contains its own central control element 41 which can be programmed to control the field station operation separately or in conjunction with the programmed control of the master controller 10. The field station 11 is provided with an eight channel digital input 42 with AC current to DC voltage converters 43 and which are normally used to sense valve or solenoid current. A further eight channel digital input 44 with a DC voltage conditioner 46 is used to sense DC valve or solenoid current.

Additionally, a 16 channel output is divided into two eight channel outputs 47 and 48, one being for relatively low power continuous or pulse output and the other for relatively high power continuous or pulse output.

An eight channel analogue two digital converter 49 receives inputs from analogue sensors via the differential or single ended amplifier 51. An eight channel output 52 associated with the analogue to digital converter 49 is able to provide electrical power to transducers when required through the electronic switch 53.

The eight channel digital input 54 is used for setting the field station identification code while the further digital input 56 is associated with configuration switches for setting the number of valves, the number of pulsed electrical outputs and the like.

Control signals to and from the field station 11 may be transmitted by radio via the radio transmitter/-receiver 59 or via an RS232 port 58 or using a current loop channel 61 or a line carrier channel 62. In each case, anti-collision signal lockout is provided by the anti-collision circuit 63.

An interface 64 is provided for a portable control unit, having a key-pad and display, enabling the central

control element 41 to be externally programmed and interrogated.

As the operations and functions being controlled are time-based, a real time clock 66 provides the appropriate time references.

The intelligent field station of Figure 3 enables irrigation apparatus controlled thereby to be under control of the master controller 10 through a program running in the master controller with the field station 11 able to interpret sensed inputs and vary the main program operation in accordance with its own program. Various field stations 11 may also communicate with each other to facilitate cyclic or sequential operation of various irrigation controls so that, as one field station 11 completes an irrigation cycle, it then signals the next station in turn to commence its irrigation cycle.

The master controller 10 and the field stations 11 each incorporate a radio transmitter operating in the UHF band (approximately 303.5 MHz) with data control and utilizing a dual carrier. The basic transmitter circuit shown in Figure 4 has a transistor 68 coupled to the FET 69 to form an oscillator operating at the main carrier frequency of around 300 MHz. The main carrier is modulated by the FET crystal oscillator in which the crystal 72 is connected to the input circuit of the FET 71 and controls the frequency to that of the crystal. In the present case, the crystal 72 is a 32 KHz crystal which is impressed on the main carrier.

Data to be transmitted, and which will include an 8 bit digital identity code, 16 bit data code and 8 bits of parity code, is supplied to the input 73 of the conditioning circuit 74 for modulation of the sub-carrier. The dual carrier signal is transmitted via the loop 76.

Each of the master controller 10 and field stations 11 has a receiver circuit of the type shown in Figure 5. The transmitted signals detected by the aerial 77 pass through the pre-amp 78 to the regenerative oscillator 60 which conditions the signal prior to demodulation.

The I-F amplifier 65 which operates at a frequency in the range of about 455 KHz directs the signal through the single chip receiver 70 and then through the crystal filter 75. If the demodulated signal is exactly 32 KHz it will pass through the crystal filter 75 to the address identification circuit of the respective field station or master controller. If the demodulated signal is not exactly 32 KHz, it will not pass through the crystal filter 75 and will, therefore, be rejected. Thus, the dual carrier transmission system ensures accurate detection of the correct signals and rejection of any spurious signals. Naturally, the crystal filter 75 is exactly the same frequency as the crystal 72 controlling the crystal oscillator of the transmitter.

The facia panel of the master controller is illustrated in Figure 6. The display 79 is a two-line, 16 character display which asks programming questions during a programming operation and shows data which has been entered. The air temperature display 80 and wind speed display 81 provide constant readings of the temperature and speed, respectively, from the weather station 32 indicated in Figure 2.

The ALARM DISPLAY has a plurality of indicators which indicate when an alarm function has operated. The alarm displays 82 are all labelled to indicate their basic function as follows:

Valve failure - indicates when a sensor detects a valve not following the commands from the controller.

Sensor failure - indicates where sensor information is not received by the controller.

Weather shutdown - indicates when entered weather parameters have been exceeded, such as high wind speed, low temperature, etc.

No flow - indicates no water flow in a line or mains.

High flow - indicates where the water flow

rate exceeds a preset level indicating broken pipes or the like.

Filter pressure - indicates when pressure or pressure differential is outside prescribed limits.

Low signal - indicates when the radio signal is of insufficient strength indicating possible battery problems in field stations or unsuitable location of aerial, or the like.

Power down - indicates failure of external power supply to the controller.

Battery low - indicates when the controller battery is in a low state.

The alarm accept button 83 disconnects an internal audio alarm and any externally connected alarm indicators such as siren, bell or the like. The temperature override button 84 allows the system to be restarted after a temperature shutdown due to a low external temperature.

On the other side of the facia there are located 16 buttons used for programming the master controller and for manual operation thereof. The mode select button 85 initiates the appropriate mode for which programming is to be carried out or input data is to be stored. Thus, selection of the mode select button 85 and the moisture set button 86 enables a moisture level to be entered in respect of any of the field stations which will then become an operating parameter of the system. Similar operating parameters may be set in respect of the time set button 87, the volume set button 88, and the other buttons labelled in Figure 6. The function of the various buttons is indicated by the labels thereon.

It will therefore be seen that the master controller 10 may be programmed to enable control of a variety of functions associated with a particular process control such as the control of irrigation of one or more

crops. The control functions will be related to the program associated with the master controller with the apparatus described herein enabling the program to function as required.

A feature of the present invention is the provision of the anti-collision circuitry associated with the transmission and reception of control signals whereby only one signal transmission may take place at any one time thereby ensuring the reception of such transmission. Without an anti-collision system of in accordance with the invention, various field stations 11 or the master controller 10 may initiate a signal transmission which may interfere with an ongoing transmission. With the signal collision avoidance system of the present invention, reception of a signal complying with the system parameters, i.e., a dual carrier signal with the sub-carrier having a frequency of 32 KHz, the collision avoidance system prevents the transmission of another signal until the end of the transmission cycle. Referring to Figure 7, the period of transmission of any signal is set by the frequency of the oscillator 93 which triggers the one-shot timer (b) 92 on each cycle. The one-shot timer (b) 92 triggers the control 94 which then enables an analogue signal to be conditioned by the converter 96, parallel to serial data conditioners 97 and pulse width modulator 98 for transmission. Other data being input at 99 may also be transmitted in the same manner. At the end of the oscillator cycle, the signal transmission ceases unless further information requires transmission.

If a control signal is being received by the associated receiver from another station or from the master controller 10, a signal is applied at 101 and the one-shot timer (a) 91 becomes active and sends an inhibiting signal to the one-shot timer (b) 92. If the oscillator 93 triggers the one-shot timer (b) 92 while it is disabled, it will not trigger the control 94 so that no transmission can take place. A short period after the other transmission is detected, the one-shot timer (a) 91 enables

the timer (b) 92 which then triggers the control circuitry and transmission will begin at the commencement of the next cycle determined by the frequency of the oscillator 93.

It will be seen that, basically, the collision avoidance system checks the channel for any other transmission, if none is found data is transmitted. If there is data present, then the circuit waits until the transmission is over and then transmits its data a short time later.

A further feature of the present invention is the use of an evaporation measuring device to provide an input to the master controller 10. The evaporation measuring device measures an evaporation rate either continuously or at predetermined intervals and transmits the measured information as data to the master controller 10. The master controller 10 is then able to either adjust the running program to take account of increased or decreased evaporation rates, such as by opening valves previously closed or by maintaining valves in an open position for longer than would otherwise be the case. Naturally, if desired, when the system is operated without an evaporation detection device, a weather authority published evaporation rate may be entered manually into the program at periodic intervals.

Naturally, the system may be subdivided into various groups or blocks which can be actuated as independent units from the master controller in accordance with requirements of different crops in each of the various blocks. Alternatively, the same crop sown at different times may also require differing irrigation requirements and therefore need to be subjected to differing irrigation throughout the various growth stages of the crop. All the differing requirements and parameters may be pre-programmed into a single master controller which can control the various field stations throughout the system.

The encoding of data for transmission from the field stations 11 to the master controller 10 may be

effected in any convenient manner. For example, where the parameter sensing means comprises a soil moisture level sensor providing a voltage level indicative of the moisture level, that voltage may be supplied to a voltage controlled oscillator which, in turn, will provide a signal of a characteristic frequency representing the moisture level to the data processor.

It will be seen from the above description that the master controller 10 need not continuously poll or monitor each field station 11, although the control program may require polling for certain irrigation systems. Otherwise, the master controller 10 will generate and transmit control signals under program control as and when required and, similarly, the field stations 11 will transmit data to the master controller 10 either on a periodic basis or when a change in sensed parameters takes place.

It will be appreciated that the operation of the process control system of the invention will be carried out in accordance with the program under which the master controller 10 operates. The program may be a time-based program controlling the field stations 11 to operate valves, etc., on a time basis. Alternatively, the operation may be structured so as to provide predetermined amounts of water at each field station in conjunction with sensed soil moisture levels.

In a third mode of operation, the master controller 10 is programmed for fully automatic control of the field stations independent of time elapsed or quantity of water dispensed. The water supply to a crop can be controlled entirely according to the need of the crop for optimum production, taking into account the crop type, soil type, stage of development, weather conditions and the like. Data relating to crop growth patterns, water requirements, fertilizer requirements and the like is generally available from Government departments of agriculture and can be used for programming the master controller 10. Naturally, an operator can manually override a program operation at any time either by direct operation of the master

controller 10 or through a remotely located, associated computer which is able to communicate with the master controller 10 via the dedicated line or telephone line and modem unit.

It will also be appreciated that, irrespective of the mode of transmission of signals between the master controller 10 and fuel stations 11, i.e., radio transmission or single, two-wire cable or dedicated line, the signal collision avoidance circuit operates to prevent simultaneous transmission of more than one control signal.

The operations or functions which can be controlled by a system in accordance with the invention are not restricted to irrigation systems or particular parts of irrigation systems. Thus, the invention is applicable to any process control or control of any type of operation or function from a central location.

Claims

1. Remote process control apparatus comprising a master controller and a plurality of slave units located remote from the master controller, each slave unit having one or more inputs receiving input signals from at least one sensing means and one or more outputs to control at least one process or operation, signal transmitting and receiving means associated with each slave unit to receive signals transmitted by the master controller and to transmit information thereto, said master controller including a programmable microprocessor and means for inserting program instructions, input means for receiving parameter signals from parameter detecting means, and control signal generating means to generate coded control signals for transmission to said slave units in accordance with programmed instructions, said master controller communicating with any of said slave units when a change of parameters beyond predetermined values occurs or at predetermined times or following signals transmitted by a slave unit in response to an input signal, and lockout means on each slave unit and said master controller to prevent transmission at any one time of more than one control or other signal by a slave unit or the master controller.

2. Apparatus according to claim 1 wherein said lockout means comprises timer means initiated by reception of a signal transmission from a slave unit or the master controller, said timer means causing generation of a blocking signal having a duration equal to the predetermined time of transmitted signal cycles.

3. Apparatus according to claim 1 or claim 2 wherein each said slave unit includes a microprocessor programmable from an associated keyboard or from program signals sent from the master controller, the slave unit controlling said at least one process or operation in accordance with the slave unit microprocessor program or in accordance with control signals transmitted by the master controller.

4. Apparatus according to claim 3 wherein control

signals are transmitted between slave units in accordance with programmed instructions.

5. Apparatus according to any one of the preceding claims wherein said master controller includes a date and time calendar and receives parameter signals from temperature sensing means and wind speed detecting means.

6. Apparatus according to claim 5 wherein said master controller receives a further parameter signal from moisture evaporation rate detecting means.

7. Apparatus according to any one of the preceding claims wherein said at least one sensing means comprises a valve position detector to detect the open or closed condition of a valve.

8. Apparatus according to any one of the preceding claims wherein input signals are received by each slave unit from sensors comprising any one or more of the group of moisture sensor, water flow sensor, filter condition sensor, motor operation sensor, pump operation sensor, air temperature sensor, wind speed sensor, precipitation sensor, daylight sensor, fertilizer injector sensor, evaporation rate sensor and soil temperature sensor.

9. Apparatus according to claim 8 wherein each slave unit initiates a signal transmission to the master controller on reception of an input signal reflecting a sensed value outside predetermined control values.

10. Apparatus according to any one of the preceding claims wherein signal transmission between the master controller and the slave units is effected by dual carrier radio transmission of binary pulses with a main carrier in the UHF range of between 250 MHz and 350 MHz and a sub-carrier of a relatively low frequency, and each slave unit and master controller is crystal-locked to the sub-carrier frequency.

11. Apparatus according to claim 10 wherein the sub-carrier frequency is 32 KHz.

12. Apparatus according to any one of the preceding claims wherein said master controller is adapted to operate from battery power enabling the controller to be trans-

ported from place to place.

13. Apparatus according to any one of the preceding claims wherein control signals transmitted by the master controller and signals transmitted by the slave units comprise 16 or more bit binary pulses which include address bits and data bits, each slave unit and the master controller having a unique address code.

14. Apparatus according to any one of claims 1 to 9 wherein said master controller and all said slave units are interconnected by a single two-wire cable for transmission of control signals.

15. Apparatus according to claim 14 wherein electrical power for operating said slave units is transmitted by said cable.

16. Apparatus according to any one of the preceding claims wherein at least one of said slave units controls a liquid valve having an electrical actuator, said actuator including solenoid means operable by an electrical pulse to cause said valve to change state between a valve open condition and a valve closed condition.

17. Apparatus according to claim 16 wherein said valve comprises a valve chamber, a liquid inlet port and a liquid outlet port communicating with the valve chamber, a valve spool axially movable in the valve chamber between a valve open position whereat the inlet port communicates with the outlet port and a valve closed position, said solenoid means being operable to move the spool, and means to retain the spool in one or other of the valve open and valve closed positions.

18. Irrigation control system comprising flood, channel, drip or spray irrigations to convey water to crops in the ground, soil moisture sensors adjacent said crops, means to cause water to flow to the irrigators and control apparatus as claimed in any one of the preceding claims to control the water flow means.

19. Control apparatus substantially as hereinbefore described with reference to the accompanying drawings.

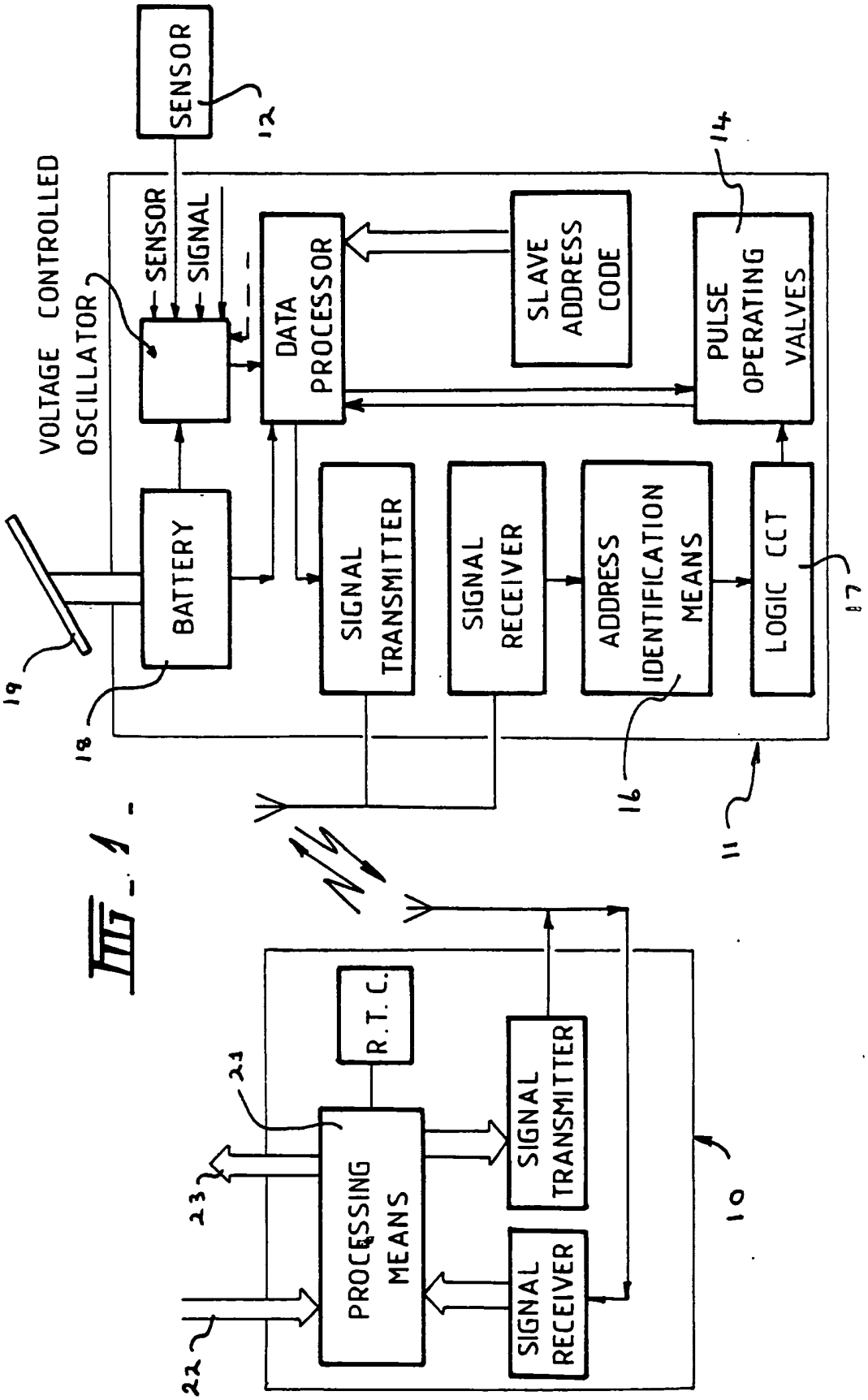

SENSOR
12
VOLTAGE CONTROLLED OSCILLATOR
SENSOR
SIGNAL
DATA PROCESSOR
SLAVE ADDRESS CODE
PULSE OPERATING VALVES
14
BATTERY
SIGNAL TRANSMITTER
SIGNAL RECEIVER
ADDRESS IDENTIFICATION MEANS
LOGIC CCT
17
19
18
16
11
R.T.C.
21
23
PROCESSING MEANS
SIGNAL TRANSMITTER
SIGNAL RECEIVER
22
10

Fig. 1

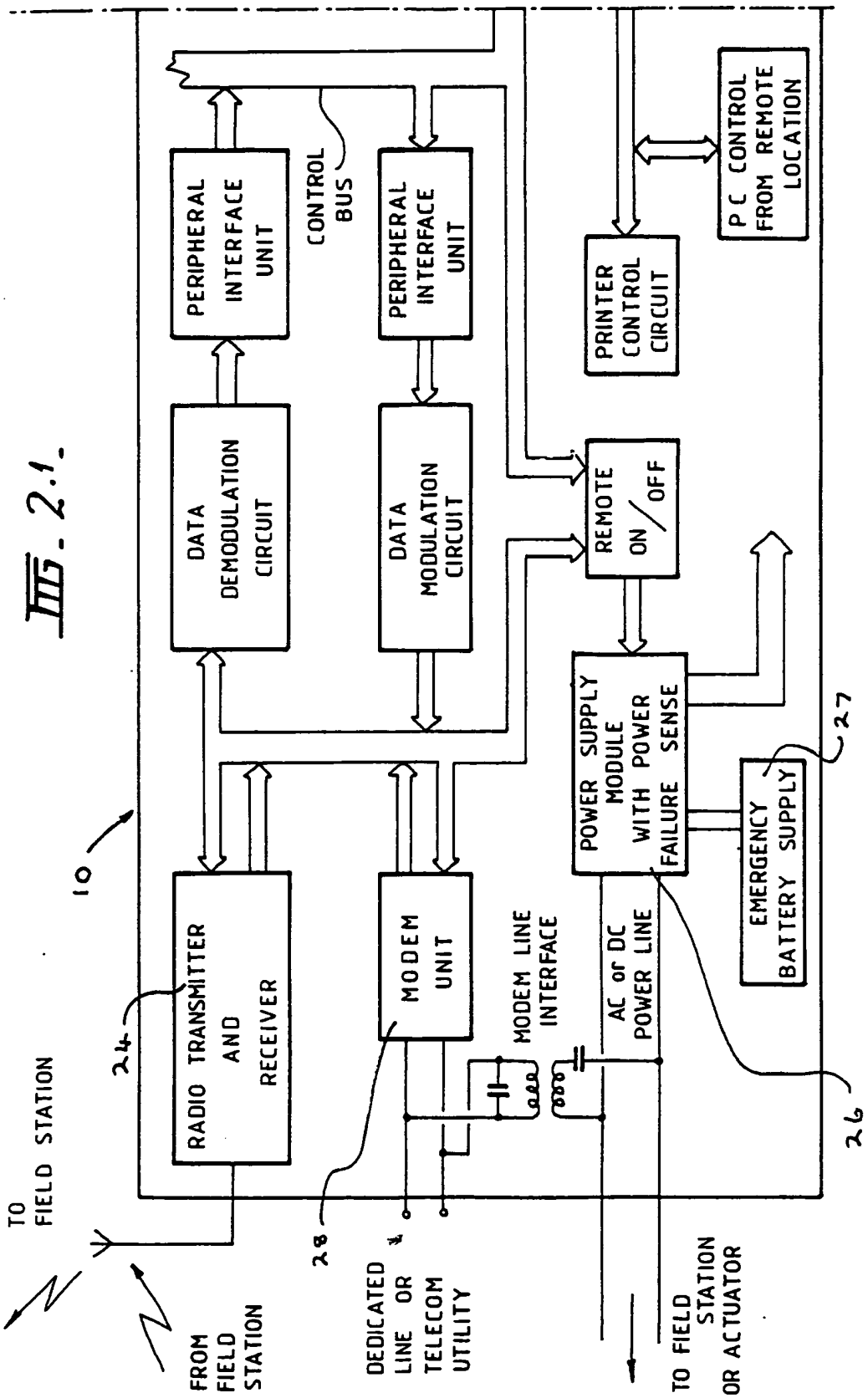

PERIPHERAL INTERFACE UNIT
CONTROL BUS
PERIPHERAL INTERFACE UNIT
PRINTER CONTROL CIRCUIT
P C CONTROL FROM REMOTE LOCATION
DATA DEMODULATION CIRCUIT
DATA MODULATION CIRCUIT
REMOTE ON / OFF
POWER SUPPLY MODULE WITH POWER FAILURE SENSE
27
EMERGENCY BATTERY SUPPLY
10
RADIO TRANSMITTER AND RECEIVER
MODEM UNIT
MODEM LINE INTERFACE
AC or DC POWER LINE
24
26
28
TO FIELD STATION
FROM FIELD STATION
DEDICATED LINE OR TELECOM UTILITY
TO FIELD STATION OR ACTUATOR

FIG. 2.1.

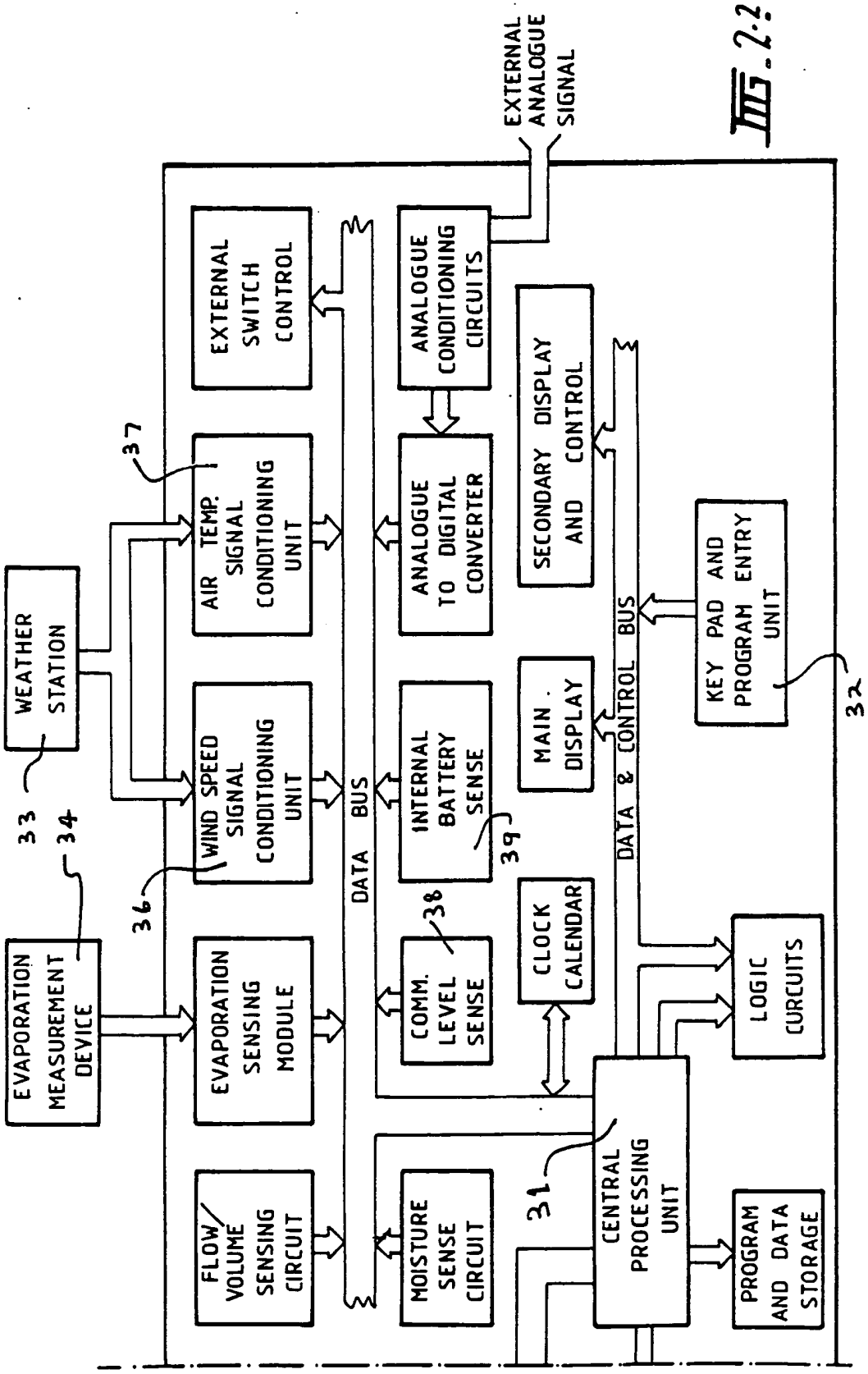
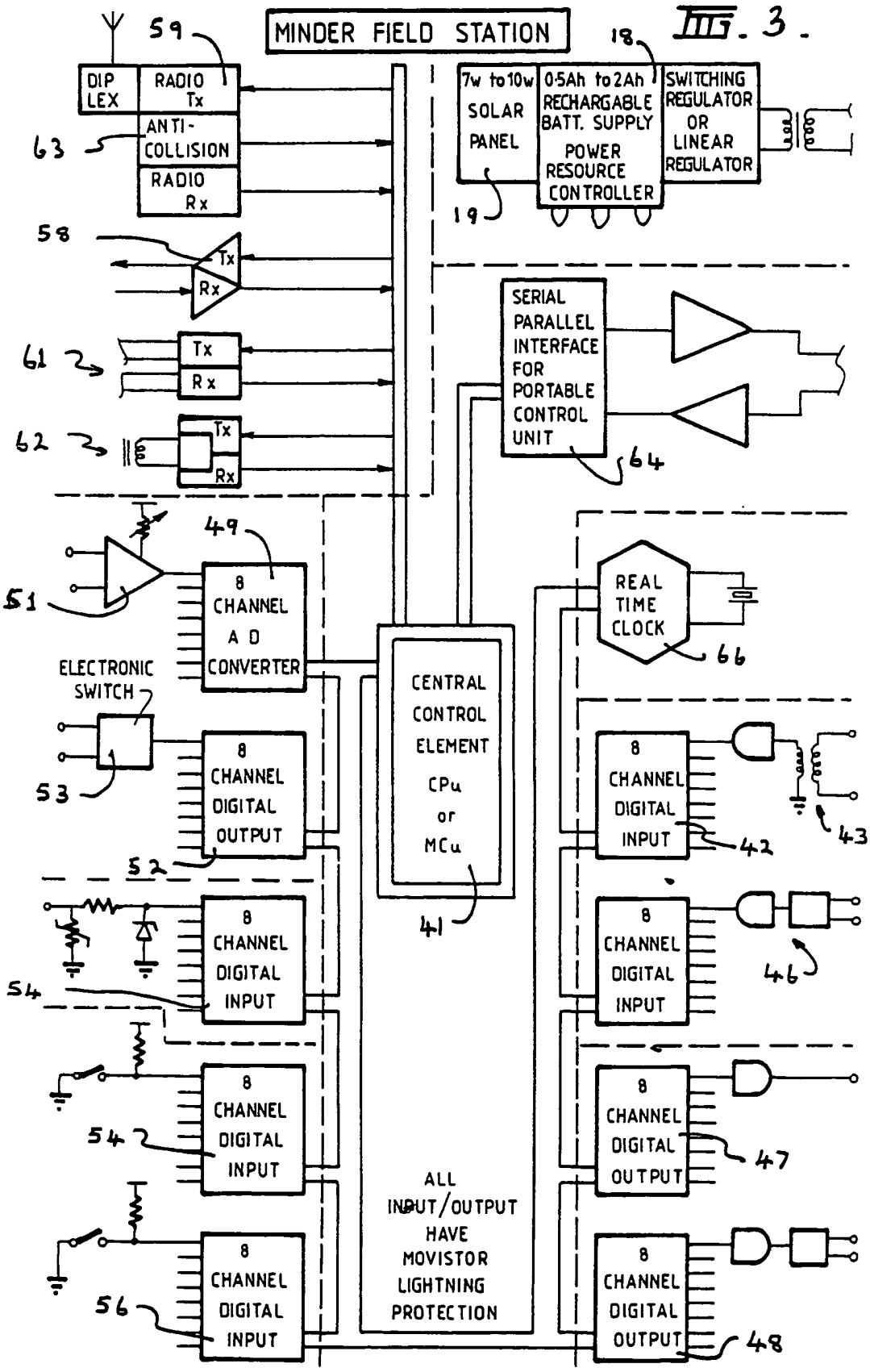

EXTERNAL ANALOGUE SIGNAL
EXTERNAL SWITCH CONTROL
ANALOGUE CONDITIONING CIRCUITS
SECONDARY DISPLAY AND CONTROL
KEY PAD AND PROGRAM ENTRY UNIT
32
37
AIR TEMP. SIGNAL CONDITIONING UNIT
ANALOGUE TO DIGITAL CONVERTER
WEATHER STATION
33
34
WIND SPEED SIGNAL CONDITIONING UNIT
INTERNAL BATTERY SENSE
39
MAIN DISPLAY
DATA BUS
DATA & CONTROL BUS
36
38
COMM. LEVEL SENSE
CLOCK CALENDAR
EVAPORATION MEASUREMENT DEVICE
EVAPORATION SENSING MODULE
LOGIC CURCUITS
FLOW VOLUME SENSING CIRCUIT
MOISTURE SENSE CIRCUIT
31
CENTRAL PROCESSING UNIT
PROGRAM AND DATA STORAGE

Fig. 2.2


MINDER FIELD STATION
FIG. 3.
59
DIP LEX
RADIO Tx
ANTI-COLLISION
RADIO Rx
63
58
Tx
Rx
61
62
18
7w to 10w SOLAR PANEL
0·5Ah to 2Ah RECHARGABLE BATT. SUPPLY
POWER RESOURCE CONTROLLER
SWITCHING REGULATOR OR LINEAR REGULATOR
19
SERIAL PARALLEL INTERFACE FOR PORTABLE CONTROL UNIT
64
49
51
8 CHANNEL A D CONVERTER
ELECTRONIC SWITCH
53
8 CHANNEL DIGITAL OUTPUT
52
CENTRAL CONTROL ELEMENT CPu or MCu
41
REAL TIME CLOCK
66
8 CHANNEL DIGITAL INPUT
42
43
46
54
47
56
48
ALL INPUT/OUTPUT HAVE MOVISTOR LIGHTNING PROTECTION

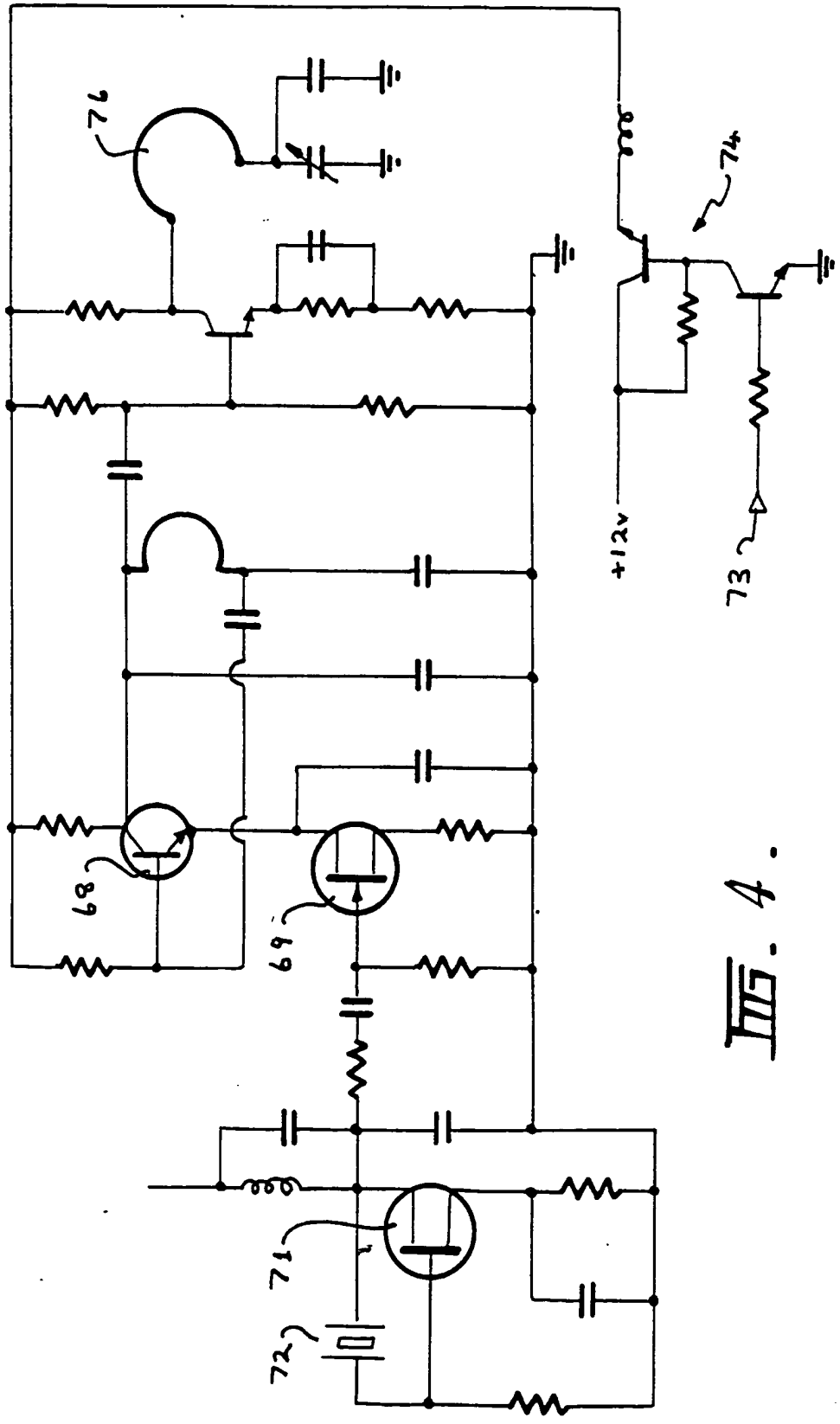


Fig. 4.

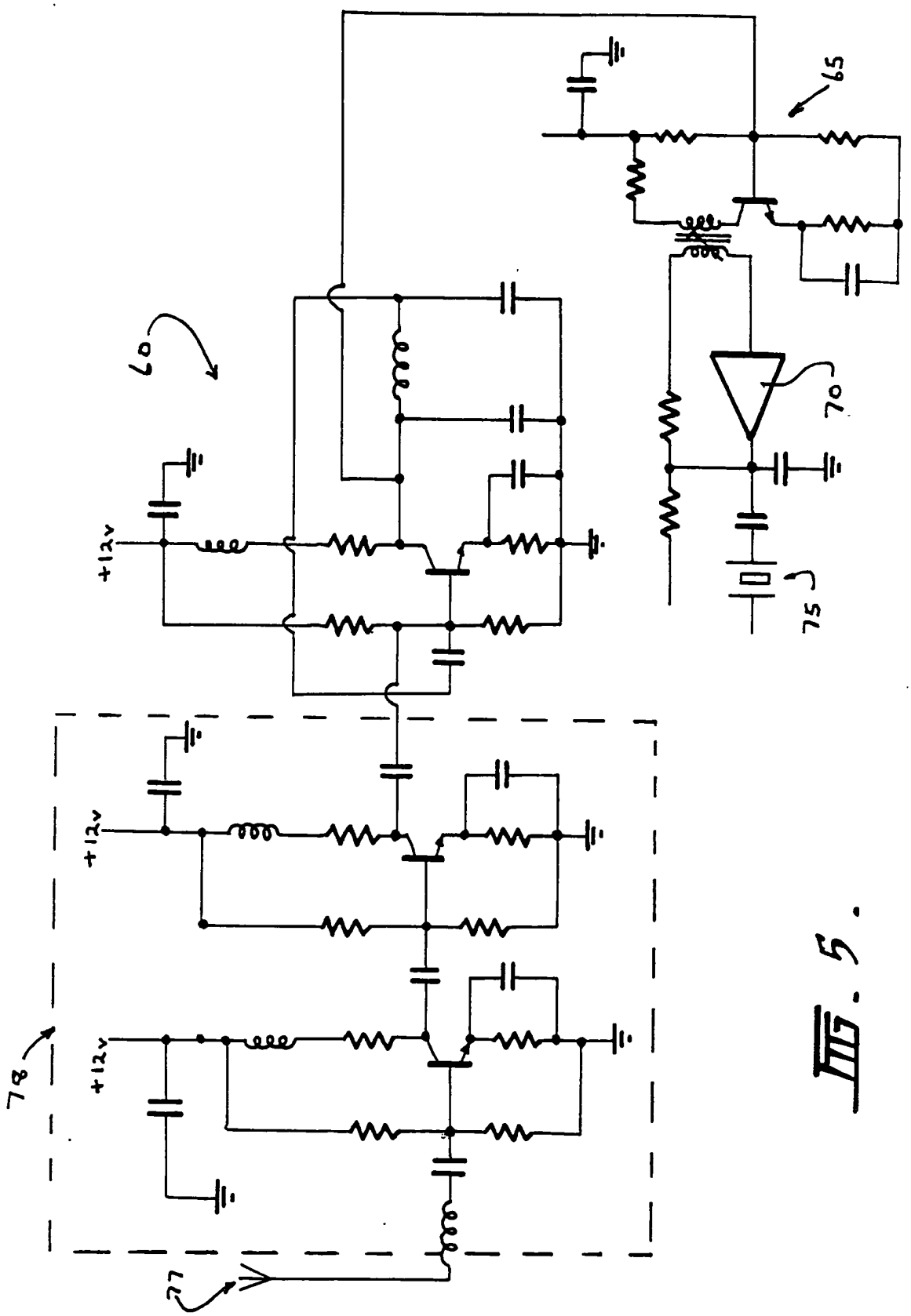


Fig. 5.

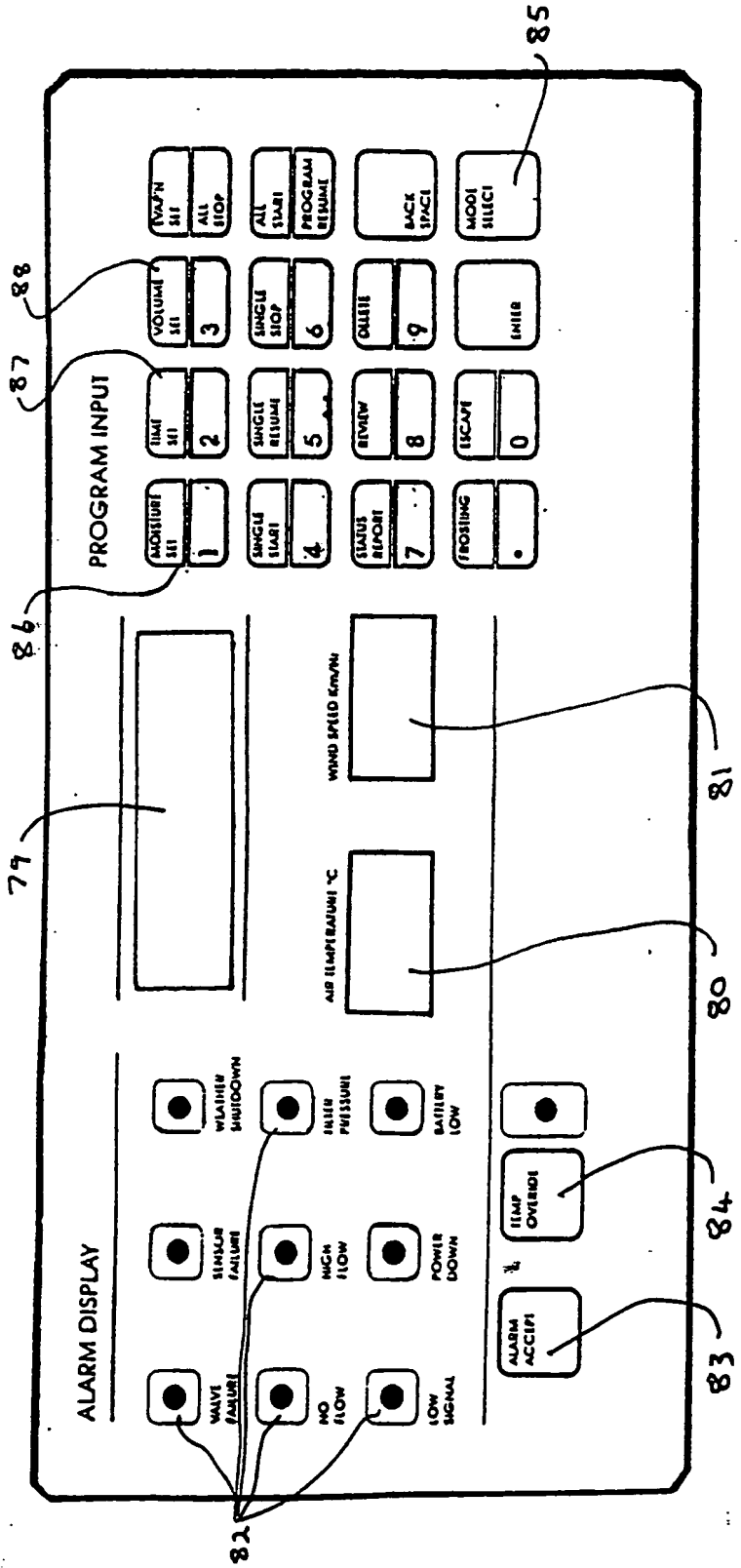

PROGRAM INPUT
ALARM DISPLAY
WIND SPEED Km/hr
AIR TEMPERATURE °C
MOISTURE SET
TIME SET
VOLUME SET
EVAP'N SET
ALL STOP
ALL START
PROGRAM RESUME
BACK SPACE
MODE SELECT
ENTER
ESCAPE
REVIEW
DELETE
SINGLE STOP
SINGLE RESUME
SINGLE START
STATUS REPORT
FROSTING
1
2
3
4
5
6
7
8
9
0
.
WEATHER SHUTDOWN
INLET PRESSURE
BATTERY LOW
SENSOR FAILURE
HIGH FLOW
POWER DOWN
VALVE FAILURE
NO FLOW
LOW SIGNAL
TEMP OVERRIDE
ALARM ACCEPT
79
80
81
82
83
84
85
86
87
88

FIG. 6.

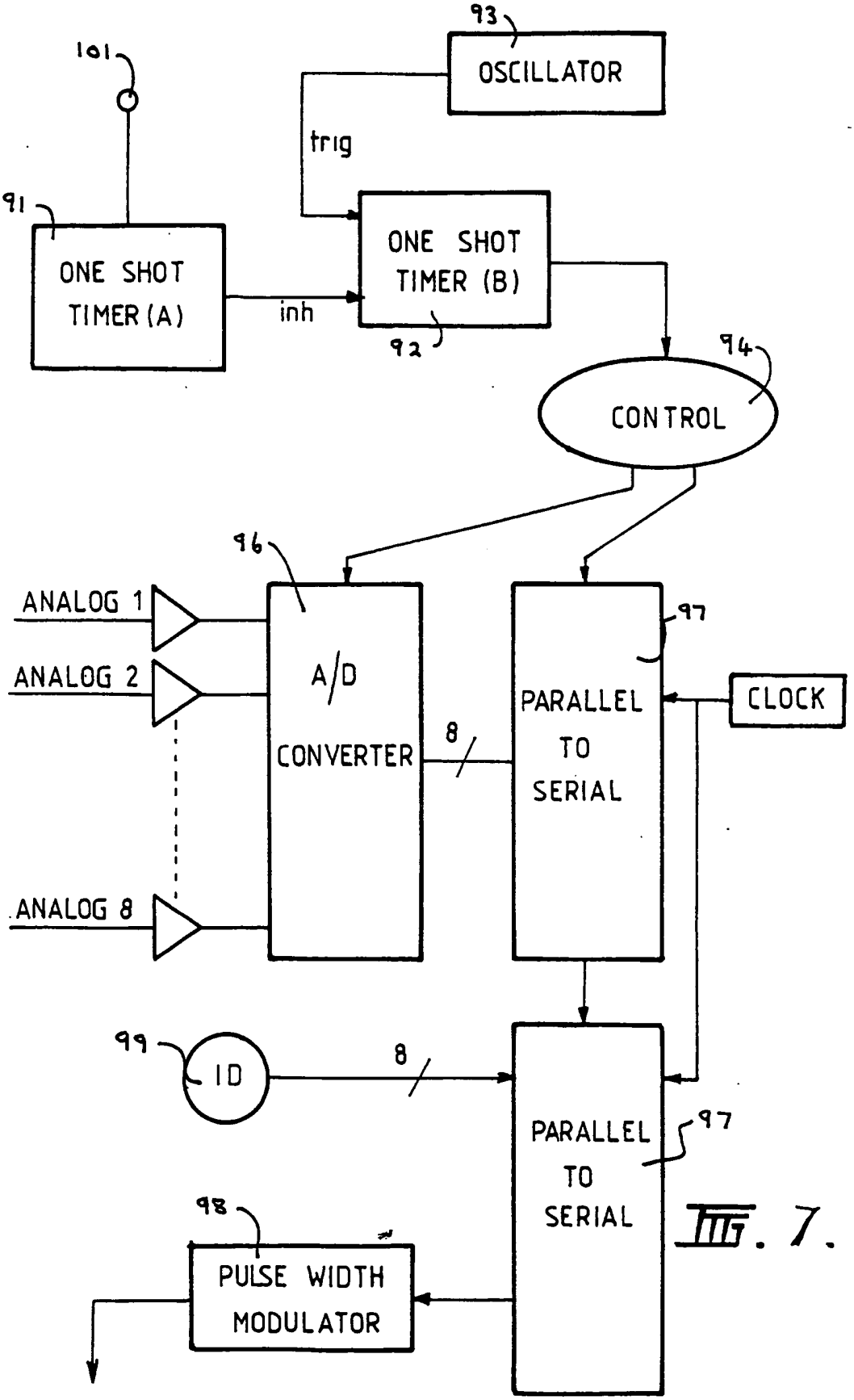

101
93
OSCILLATOR
trig
91
ONE SHOT TIMER (A)
inh
ONE SHOT TIMER (B)
92
94
CONTROL
96
ANALOG 1
ANALOG 2
ANALOG 8
A/D CONVERTER
8
97
PARALLEL TO SERIAL
CLOCK
99
ID
8
PARALLEL TO SERIAL
97
98
PULSE WIDTH MODULATOR

FIG. 7.

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 87/00008

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[4] G05B 15/02, A01G 25/16

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	G05B 15/02, A01G 25/16

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU: IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	AU,A, 22777-83 (TOKYO SHIBAURA DENKI KABUSHIKI KAISHA) 28 June 1984 (28.06.84)	
A	AU,A, 18010-83 (HORNABROOK) 21 February 1985 (21.02.85)	
A	FR,A, 2515839 (STE SE II SA.-FR.) 6 May 1983 (06.05.83)	
A	US,A, 4541563 (UETSUHARA) 17 September 1985 (17.09.85)	
A	US,A, 4396149 (HIRSCH) 2 August 1983 (02.08.83)	
A	US,A, 4165532 (KENDALL, et al) 21 August 1979 (21.08.79)	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
8 April 1987 (08.04.87)	23 APRIL 1987
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	P. Gerondal P. GERONDAL

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 87/00008

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members
AU 22777/83	EP 115178, JP 59116897
AU 18010/83	AU 50145/79
US 4541563	JP 59017734
US 4396149	US 4567563

END OF ANNEX